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ON THE ARRANGEMENT OF TELEGRAPH BATTERIES.

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MR. GRAVES, in his article on "Telegraphic Batteries," which appeared in No. III. of this Journal, is perfectly right in saying that the arrangement of batteries is frequently unsuited to the circuit through which they are working. I have myself not unfrequently seen cells joined up in series,—that is, the copper of one cell to the zinc of the next, and so on,—to work an electro-magnet of less than 1 ohm resistance, the whole circuit being composed simply of the battery and this electro-magnet. Unfortunately Mr. Graves, by using the words "quantity" and "tension" in the old-fashioned vague way, has prevented his article from being very clear; he also does not appear to see that the whole of his experimental results could have been predicted from a simple consideration of Ohm's law.

In a battery there are four distinct things to be considered:—

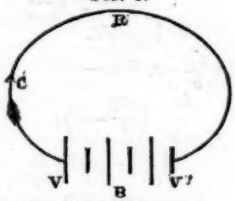
The electro-motive force (E), or difference of potentials between its two poles when insulated from one another.

The difference of potentials (V—V') between its two poles, when they are joined through any particular resistance (R).

The internal resistance (B) of the battery.

The current (C) that flows through the circuit in any particular case.

FIG. 1.



And Ohm's law tells us that—

$$C=\frac{E}{B+R}=\frac{V-V'}{R}.$$

Now let V'=0, which is the case where R represents the resistance of an ordinary telegraph line, then—

$$C=\frac{E}{B+R}=\frac{V}{R}. \quad \ldots \quad (1)$$

Now if the number of cells in series be doubled, then, assuming all the cells to be alike,—

E will be doubled,
and B will be doubled;
therefore if R also be doubled,
C will remain constant;
therefore V must be doubled.

Similarly, if the number of cells in series and also R be trebled,—

V will be trebled, &c.

And this is all Mr. Graves shows in his first and second series, page 41.

Now from his series on page 42, I see that the internal resistance, B, of his battery, was about 300 V. U.

Substituting this value in equation (1) we have—

if R= ∞ then V= E, which he has called 120;

if R= 0 „ V= 0;

if R= 100 „ $V=100.\frac{120}{300+100}$
$=30;$

if R=1000 „ $V=1000.\frac{120}{300+1000}$
$=92;$

therefore his third series of results could also have been predicted from Ohm's law.

Mr. Graves then goes on to speak of "tension in use" and "tension to spare," and "of charging a circuit to its fullest tension." What he means by this is not at all clear; I presume by "tension to spare" Mr. Graves means to say that the difference of potentials between the two poles of a battery, when joined by a small resistance, is less than the difference of potentials when joined by a large resistance: no electromotive force, however, can be spoken of as to spare, since in any battery of which the arrangement of the cells is kept constant the difference of potentials between its two poles, or the electromotive force employed in sending the current through the external resistance, added to the electromotive force employed in sending the current through the internal or battery resistance is always constant, no matter whether the external resistance be small or great, and is equal to the whole electromotive force of the battery,—that is the difference of potentials between its two poles when insulated from one another; or shortly electromotive force employed externally plus electro-motive force employed internally is always constant for any particular battery.

In paragraph 7, page 42, Mr. Graves falls into a curious error. He thinks that in the case of a short, badly insulated line, whose circuit resistance is so small that a greater current may be got from a considerable number of cells if they be arranged partly in series, that is copper to zinc, and partly in parallel circuit, that is copper to copper, than could be got from the same number of cells if all joined in series,—in such a case I say Mr. Graves thinks that the tendency to leakage would be less with the first arrangement than with the second, or, in other words, that in the case of a line of which the other end is to earth it may be possible to send a greater current into the line with some particular arrangement of cells than with some other, while yet, at the same time, the potentials respectively of every point of the line in the first case are less than the potentials of the same points in the second case. Mr. Graves quite forgets that in the case of a line of which the other end is to earth, then as long as the wire resistance, the insulation resistance, and the position of the resultant fault remain constant, the current entering the line is directly proportional to the potential of the point at which it enters the line, and this quite independently of the form or kind of battery by which the current is produced; also that the potential of every other point of the line bears a definite proportion to the potential of

the first point of the line, which proportion depends solely on the wire and insulation resistances of each portion of the line, and not at all on the battery. Consequently in such a case greater current must be accompanied with greater potential of every point, and, therefore, with greater tendency to leakage, no matter by what arrangement of cells this greater current is produced.

The whole question entered into in Mr. Graves' paper may be put in a few words as follows:—

Let R be the circuit resistance of a line; by that I mean the resistance that would be found by testing the line when its other end was put to earth through the receiving-instrument in the ordinary way. This resistance, in long or badly-insulated lines, will be that of a parallel circuit composed partly of wire resistance and partly of insulation resistance.

Let n be the number of cells joined in series,
m be the number of cells joined in parallel circuit,
e be the electromotive force of each cell,
b be the internal resistance of each cell,
C be the current leaving the sending-station,
c be the current arriving at the receiving-station,

then—

$$C=\frac{ne}{\frac{nb}{m}+R},$$

and—

$$c=kC,$$

where k depends solely on the wire and insulation resistance and on the position of the resultant fault, and is quite independent of the battery. As long as the electrical conditions of the line remain constant, k may be considered as a constant. Now—

$$c=k.\times\frac{ne}{\frac{nb}{m}+R},$$

therefore, no matter what n, m, or R may equal, increasing n or m, or both, will always increase c.

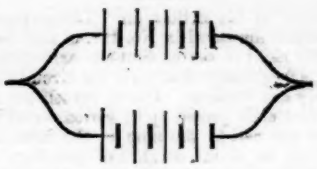
If, however, only a fixed number of cells be available, the product $(n\times m)$ must be constant. One of the factors, therefore, cannot be increased without diminishing the other. Consequently it is of importance to know what should be the value of each factor in any particular case. This is solved in a general way by the rule derived from theoretical considerations, and which is commonly given in books, viz., that any fixed number of cells give the maximum current through a definite resistance when the cells are so arranged that their internal resistance is as nearly as possible equal to the external resistance. From this is at once derived the ordinary corollary that when the external resistance is very small the cells should be arranged all in parallel circuit, and when the external resistance is very large the cells should be arranged all in series. Next comes the following practical question, which is not usually answered in books, or at any rate not in a simple practical way. Suppose it be required to work a circuit having a resistance of, say, more than 100 B.A. units, we of course try a few cells in series; if these do not give sufficient current, we try more cells joined in series. Now the question arises, if we require to put on more and more cells before we can get a current of the desired strength, where should we stop putting on cells in series and commence joining them in parallel circuit? And this is the question I propose considering.

Let the whole number of cells (N) under trial be joined in series, and let (C_1) be the current arriving at the receiving station, then—

$$C_1=k.\frac{Ne}{Nb+R}.$$

Now let these N cells be joined in pairs thus:—

FIG. 2.



that is, only $\frac{N}{2}$ in series, and let (C_2) be the current now arriving at the receiving station, then—

$$C_2=k\frac{\frac{N}{2}e}{\frac{Nb}{4}+R}$$

$$=k\frac{Ne}{\frac{Nb}{2}+2R}.$$

Now the question is, when is C_1 less than, equal to, or greater than C_2?

Let $C_1=C_2$, then—

$$k\frac{Ne}{Nb+R}=k\frac{Ne}{\frac{Nb}{2}+2R},$$

$$\text{or } Nb=2R.$$

Next let $N=\frac{2R}{b}-a$, then—

$$C_1=k\frac{\left(\frac{2R}{b}-a\right)e}{\left(\frac{2R}{b}-a\right)b+R},$$

$$\text{and } C_2=k\frac{\left(\frac{2R}{b}-a\right)e}{\left(\frac{R}{b}-\frac{a}{2}\right)b+2R};$$

From which it is obvious that—

$$C_1>C_2.$$

Next let $N=\frac{2R}{b}+a$, then—

$$C_1=k\frac{\left(\frac{2R}{b}+a\right)e}{\left(\frac{2R}{b}+a\right)b+R},$$

$$C_2=k\frac{\left(\frac{2R}{b}+a\right)e}{\left(\frac{R}{b}+\frac{a}{2}\right)b+2R};$$

From which it is obvious that—

$$C_1 < C_2.$$

From this it follows that to work such a circuit as we are considering, first try a few cells in series; if these do not give sufficient current put more and more cells in series, until either sufficient current be obtained, or until the resistance of the battery is *double* that of the line. At this point halve the battery, joining the cells in pairs, as in Fig. 2. For this particular number of cells this arrangement will give exactly the same current as when the whole number were joined in series.

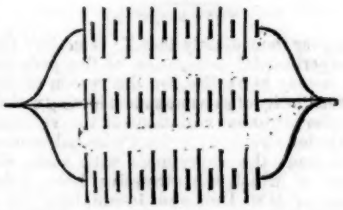
Now, to increase the current, put on extra cells in pairs, one cell being added to each of the two rows in series.

Then, by a consideration precisely similar to the preceding, it may be shown that, to increase the current more and more, this mode of adding extra cells should be continued until—

$$Nb = 6R,$$

that is, until the whole number of cells employed is such that if all were joined in series their resistance would be six times the external resistance. At this point the cells should be joined in threes thus (Fig. 3), so that the whole number in series is $\frac{N}{3}$:—

Fig. 3.



For this particular number of cells this arrangement will give the same current as the last arrangement, where half the whole number were joined in series. Now to increase the current still more, put on extra cells in threes, one cell being added to each of the rows in series, &c. Of course all this is but an example of the general law of getting the maximum current from a definite number of cells. Nevertheless giving the solution of the question as I have given it may perhaps tend to prevent those absurd and unscientific arrangements of cells one not unfrequently sees.

The next point I will consider is the *relative number of cells required at the two ends of a line of which the insulation is not uniform.*

Let I be the absolute insulation of the line, that is the real parallel resistance of the insulators, independent of the wire resistance.

Let the wire resistance of the line, up to the position of the resultant fault, be L from one end of the line, M from the other end. By this I mean to say that if a single leakage having a resistance (I) were—instead of all the other leakages—substituted at a point (p) so taken that the wire resistances of the line from the two ends up to this point were L and M respectively, then that the electrical conditions of the line would remain unaltered.

Let r be the resistance of the receiving-instrument employed at each end of the line.

Then if x be the number of cells employed at l,

y " " " " m,

Q be the current arriving at m,

S " " " l,

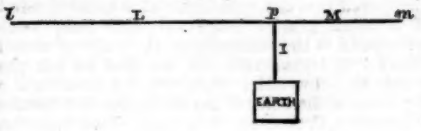
and if the cells at both ends be joined in series, which is usually the case in telegraph lines, then—

$$Q = \frac{I}{I+M+r} \times \frac{xe}{xb + L + \frac{I(M+r)}{I+M+r}},$$

$$S = \frac{I}{I+L+r} \times \frac{ye}{yb + M + \frac{I(L+r)}{I+L+r}},$$

In order that Q may equal S,—that is, in order that the instruments at each end of the line may work equally well.

Fig. 4.



$$\frac{x}{(I+M+r)\left(xb + L + \frac{I(M+r)}{I+M+r}\right)} =$$

$$= \frac{y}{(I+L+r)\left(yb + M + \frac{I(L+r)}{I+L+r}\right)}$$

On a long line, in which this consideration is the most interesting, xb and yb can both be neglected in comparison with the other resistances.

$$\therefore \frac{x}{(I+M+r)L + I(M+r)} = \frac{y}{(I+L+r)M + I(L+r)}.$$

Let $L = uM$, then—

$$\frac{x}{y} = \frac{(I+M+r)uM + I(M+r)}{(I+uM+r)M + I(uM+r)},$$

$$= \frac{u(IM + M^2 + rM) + I(M+r)}{u(IM + M^2) + rM + I(M+r)}.$$

$\therefore$ if $u > 1$,
then $x > y$;
and if $u < 1$,
then $x < 1$;

therefore the station at the worse insulated end of the line requires less battery power than the station at the other end of the line, in order that the current arriving at both ends may be the same. This investigation is the more interesting as it is the opposite of what one might have felt inclined to predict from an *a priori* consideration.

Pentland Firth Cable.—The damage to the Pentland Firth telegraph cable has been remedied, and communication between the main land and Orkney is again established.

Electric Light at Westminster.—We are informed that the light at present exhibited on the top of the clock tower at Westminster is about to be changed for two experimental lights, one a powerful gas light, the other magneto-electric. The former will be shown on the west side of the tower, the latter on the north. The electricity will be supplied by means of machinery, similar to that described by us last month, on M. Gramme's system.

ON THE

CONDITIONS OF THE MAXIMUM RESISTANCE OF GALVANOMETERS.

By M. Th. DU MONCEL.

M. SCHWENDLER, and several other physicists before him, have found that, for a galvanometer to attain the best possible conditions of sensibility with regard to a circuit of given resistance, it is necessary that the resistance of the magnetising helix should equal that of the exterior circuit with which it is put in connection. Several experiments having shown me that this sensibility increases with the length of the wire of the helix under conditions other than those that have been indicated, I have calculated the galvanometric effects with regard to a circuit of given resistance, and I have discovered that the conditions of sensibility admit of a much greater length of wire than would correspond to the resistance of the exterior circuit. In order to demonstrate the law that he has proposed, M. Schwendler calculates the number t of the turns of the helix of the multiplier as a function of the space, C, occupied by the wire of the helix, and also as a function of its resistance H. Designating by s the section of the wire, the number t of the turns of the spiral becomes equal to $\frac{C}{s}$, and the length, H, of the helix to $\frac{Ct}{s}$. Given this, it results from the combination of the values of t and of H, that t should be expressed by $\sqrt{H}$, and as the intensity of the current has for its value—

$$\frac{E}{R+H}$$

(R designating the resistance of the exterior circuit, E the electromotive force of the electric source), the magnetic moment of the needle should be—

$$F=\frac{E\sqrt{H}}{R+H},$$

an expression which is susceptible of a maximum, R=H. But in reality the value of t is far from being expressed by $\sqrt{H}$, and if we substitute in the preceding formula the true quantities we arrive at totally different results. In effect, designating by a, the thickness of the layer of turns; by b, the width of the galvanometer frame; by c, the diameter of the circular part terminated by each side; by d, the length of the frame from the two circular parts; and, finally, by g, the diameter of the wire comprising its insulating covering, the number of turns of t should be expressed by $\frac{ab}{g^2}$ and the length, H, of the helix by—

$$H=\frac{ab}{g^2}[(a+c)\pi+2d];$$

consequently the magnetic moment, F, of the needle should be—

$$F=\frac{aEab}{g^2R+ab[(a+c)\pi+2d]},$$

a being the constant of the instrument. Now, the conditions of the maximum of this formula, taking for the variable a, which is the only quantity proportional to t, leads to the relation—

$$R=\frac{\pi ba^2}{g^2},$$

which shows that the resistance of the wire of the galvanometer should be greater than that of the exterior circuit by a quantity represented by—

$$\frac{ab}{g}(\pi c+2d).$$

We can easily assure ourselves of the truth of this deduction by supposing the frame of the galvanometer represented by a simple bobbin, as in the Thomson galvanometer, and by taking the magnetic moment of the needle with the two lengths of wire as corresponding to the two conditions of maximum given by M. Schwendler and by me. To simplify the calculation, we will represent the diameter c by $2r$. Under these conditions the length, H, of the helix in the place of being greater than the resistance, R, by a quantity represented by—

$$\frac{ab}{g^2}(\pi c+2d),$$

should be greater by only the quantity—

$$\frac{ab}{g^2}\pi c,$$

or with regard to R, as $a+2r$ is to a. Whence M. Th. du Moncel deduces that—

$$\frac{F'}{F}=\frac{a+2r}{\sqrt{a^2+2ar}+r}.$$

As $a+2r$ can be put under the form—

$$\sqrt{a^2+ar+r^2}+r$$

we discover immediately that F' is greater than F. The experimental verification of the deduction it is not so easy to realise, for the reason of the too great sensibility of galvanometers having resistance, and to the continual variations of the resistance of the exterior circuit with short wire galvanometers. I have made the experiment with some electro-magnets of which the attractive force, following the laws of MM. Dub and Jacobi, bear the same conditions of maximum with regard to the resistance of the magnetising helices, as I have shown necessary in my researches on the best construction of electro-magnets. Here are the results that I have obtained with a similar electro-magnet (and with a pile of 20 Daniell elements), to which I adapt successively magnetising bobbins of two different resistances, one having a resistance of 75 kilos. of telegraph wire of 4 m.m. diameter, the other a resistance of 200 kilos. Finally, to avoid static reactions, the attractive forces were measured with the armature at a distance of 1 m.m.

Electro-magnetic Forces with Bobbins of 75 k.m. Resistance.

	m.	m.	Attractive Force. gr.
Exterior circuit ...	18620+	0	80·0
" " ...	18620+	100000	15·0
" " ...	18620+	200000	5·5
" " ...	18620+	370000	0·0

Electro-magnetic Forces with Bobbins of 200 k.m. Resistance.

	m.	m.	Attractive Force. gr.
Exterior circuit ...	18620+	0	58·0
" " ...	18620+	100000	25·0
" " ...	18620+	200000	14·0
" " ...	18620+	370000	0·0

The wires of these circuits were perfectly insulated, and the times of the closing of the circuit were long enough to develope the maximum magnetic power. Now, we see by these figures that it is when the resistance of the bobbins is much superior to the exterior resistance that the maximum is attained, and that, for the exterior circuit of 100 kilos., the maximum is obtained with helices of 200 kilos.; that is to say, with helices presenting twice the resistance. Calculation leads to the same deduction, for, in the electro-magnet in question, the depth, *a*, of the helix was equal to the diameter, *c*, of the the electro-magnet, and consequently the value of H, which should be equal to—

$$R\frac{a+c}{a}$$

in order to satisfy the conditions of maximum, is found equal, under the conditions of my experiments, to 2R.

ELECTRIC REPLENISHERS.

Since the application by Sir Wm. Thomson of the reciprocal electrophorus principle to his "syphon recorder," and since the patenting of Mr. Varley's inductive machine, considerable attention has been directed to this class of electrical instruments. And it may interest our readers to briefly review the progress of these instruments towards their present standard.

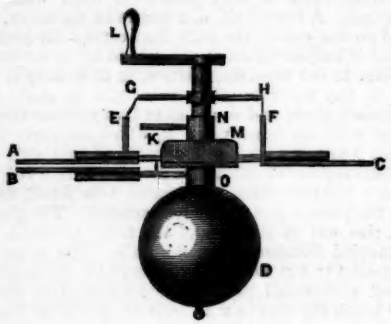
Sir Wm. Thomson, in April, 1868, said, "On having had my attention called to Nicholson's 'Revolving Doubler,' I find in it the same compound interest principle of electrophoric action. It seems certain that the discovery is Nicholson's, and about one hundred years old. Holtz's now-celebrated electric machine, which is closely analogous in principle to Varley's of 1860, is, I believe, a descendant of Nicholson's. Its great power depends on the abolition by Holtz of metallic carriers, and of metallic make-and-break contacts. Its inductive principle is identical with that of Varley's earlier and my own later invention. It differs from Varley's and mine in having the inductors to themselves, and using the current in the connecting arc, which, when sparks are to be produced, is broken."

The object of these instruments, it is almost needless to say, is to increase, by continual inductive processes, the least conceivable quantity of electricity, until a spark is obtained or the effects are observable on a common gold-leaf electrometer. The principle may be explained by reference to an instrument of this class invented by Mr. Bennet. It consisted of a circular brass plate, 3 or 4 inches in diameter, thinly varnished on the upper surface. Upon this varnished surface was placed another brass plate, of equal diameter, polished and varnished on both sides, with an insulated handle attached to one edge of it. A third plate was also provided, of equal diameter, polished and varnished on the under side, and with a perpendicular insulating handle extending from the centre of the upper side. A slight charge of electricity is communicated to the under side of the first plate, while connection with the earth is formed by the finger placed in contact with the second plate. The latter is then removed from the first plate by its insulating handle, and the third plate is placed upon the second. The third plate is then connected to earth by the finger, and separated from the second. The result of this process is that two of the plates are charged with one kind of electricity, of nearly equal quantity, and one of the plates with the other kind of electricity. The third plate is now applied to the under surface of the first plate, the first plate being covered by the second, and the second touched by the finger. By removing the third plate, withdrawing the finger from the second, and raising this plate from the first, the electrical charge becomes doubled. By repeating the operation twenty times, the original charge of electricity is increased five hundred thousand times. But the operation becomes tedious, and a mechanical arrangement, as in Nicholson's "Doubler," was speedily substituted. This instrument is thus described in a recent article on the subject, by our American contemporary, the *Journal of the Telegraph*:—"It is supported on a glass pillar, 6½ inches long, and consists of two fixed plates of brass, A, C, 2 inches in diameter (Fig. 5), separately insulated, and placed in the same plane, so that a revolving plate, B, may pass near them without touching. A brass ball, D, 2 inches in diameter, is fixed on the end of the axis that carries the plate, B, and is loaded within at one side to act as a counterpoise to the revolving plate B, so as to keep it at rest in any position. The axis, P, O, is made of varnished glass, and so are axes that join the three plates with the brass piece M, which supports the plates A and C. At one extremity of this axis is the ball D, and the other is connected with a rod of glass, N O, upon which the handle L is fixed, and also the piece G H, separately insulated. The pins, E, F, rise out of the back of the fixed plates, A, C, at unequal distances from the axis. The piece K is parallel to G H, and both of them have their ends armed with small pieces of steel wire, that they may touch the pins E F in certain points of their revolution. In the piece M there is fixed a pin, I, which intercepts a small wire proceeding from the revolving plate, B. These wires are so adjusted by bending that when the plate B is exactly opposite to D, the piece G H connects the two fixed plates, while the wire and pin at I form a connection between the ball D and the plate B. On the contrary, when the plate B is exactly opposite to the plate C, the ball D becomes connected with C by the contact of F with the wire at K, the plates A and B being then completely unconnected with any other part of the apparatus. In all other positions the three plates and the ball will be perfectly unconnected with each other."

Recurring to Sir W. Thomson's system of reciprocal induction, we find his instrument, or replenisher, for recording the signals of the Atlantic cable described in the *Proceedings of the Royal Society*. The machine is easily maintained in constant revolution by the wheelwork of an ordinary Morse instrument. A wheel of vulcanite, with a large number of pieces of metal (called carriers, for brevity) attached to its rim, is kept rotating rapidly round a fixed axis. The carriers are very lightly touched, at opposite ends of a diameter, by two fixed tangent springs. One of these springs (the earth spring) is connected with the earth, and the other (the receiver spring) with an insulated piece of metal called the receiver, which is analo-

gous to the "prime conductor" of an ordinary electric machine. The point of contact of the earth spring with the carriers is exposed to the influence of an electrified body (generally an insulated piece of metal) called the inductor. When this is negatively electrified each carrier comes away from contact with the earth spring, carrying positive electricity, which it gives up, through the receiver spring, to the receiver. The receiver and inductor are each hollowed out to a proper shape, and are properly placed to surround—each as nearly as may be—the point of contact of the corresponding spring. The inductor is kept electrified to a constant potential, and this is effected by an adjunct called the replenisher. The replenisher consists chiefly of two properly-shaped pieces of metal called inductors, which are fixed in the neighbourhood of a carrier-wheel, such as that described above, and four fixed springs touching the carriers at the ends of two diameters. Two of these springs (called receiver springs) are connected respectively with the inductors, and the other two (called connecting springs) are insulated and connected with one another (one of the inductors is generally connected with the earth and the other insulated. They are so situated that they are touched by the carriers on emerging from the inductors, and shortly after the contacts with the receiver springs. If any difference of potential between the inductors is given to begin with, the action of the carriers, as is easily seen, increases it, according to the compound interest law, as long as the insulation is perfect. Practically, in a few seconds after the machine is started running, bright flashes and sparks begin to fly about in various parts of the apparatus, even although the inductors and connectors have been kept for days as carefully discharged as possible. Forty elements of a dry pile (zinc, copper, paper), applied with one pole to one of the inductors, and the other for a moment to the connecting springs and the other inductor, may be used to determine, or to suddenly reverse, the character (vitreous or resinous) of the electrification of the insulated inductor. Following this description, Sir W. Thomson details the application to his syphon recorder, adding that, in the instrument then made, with which some remarkable results were obtained, the carrier-wheel was only 2 inches in diameter. To describe the applications would now take too much space; we hope to refer to them in a future paper.

Fig. 5.

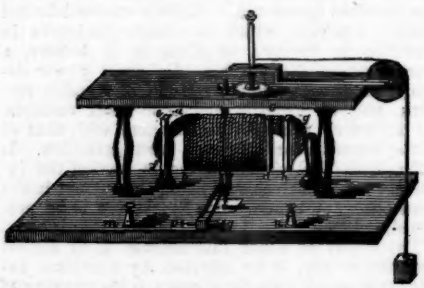


DESCRIPTION OF AN ELECTRO-MAGNETIC ROTATORY APPARATUS.*

By G. KREBS.

The many small electro-magnetic apparatus which are described in text-books of natural philosophy serve to indicate that we are in a position to apply electricity to the performance of mechanical work. These contrivances consist, for the most part, of a fixed horse-shoe electro-magnet and of one capable of rotation. On the axis on which the latter revolves a wheel is usually fixed which works into another larger one, to the axle of which a cord is fastened, which passes over a roller, below which a weight can be suspended.† All these apparatus are so constructed, however, that they work at a disadvantage. It will be found on inspection that the surfaces of the poles of both electro-magnets are so arranged that they are never sufficiently directly opposite to one another to exert a powerful attraction and repulsion. The apparatus, therefore, requires a pretty strong galvanic current—say that produced by from four to six pairs of good Bunsen elements—in order to raise but a small weight, a result which might seem to indicate that it is not practicable, in the present state of the science, to make use of electricity as a motive power. However, it is possible to get more work out of these contrivances—even the small apparatus of the lecture-room—provided they are somewhat differently arranged, and especially if care be taken that the surfaces of the poles are sufficiently large. The little rotatory apparatus represented in the accompanying illustration was constructed in the workshop

Fig. 6.



of Professor Carl, in Munich, and gives very satisfactory results with only two good pairs of Bunsen elements. The revolving electro-magnet, *a b c d*, consists of an iron plate 18 c.m. long and 9 c.m. high, the thickness being ½ c.m. in the middle and 1 c.m. at the ends or poles, *a b* and *c d*. This iron plate can turn on an axis passing through the centre, on the upper portion of which axis is a toothed wheel, and on the lower a commutator to which two long springs are attached. The fixed electro-magnet, *e f g h*, consists of a bent iron bar, 9 c.m. high and 1 c.m. thick at the poles, *e f* and *g h*, whence it diminishes towards its centre, where it is 3 c.m. high and ½ c.m. thick. Both electro-magnets are enveloped by insulated copper-wire; *m* and *n* are the clamping-screws for the coil of the fixed

* Translated from "Poggendorff's Annalen."

† See Frick's "Physik. Technik.," 3rd edit., p. 520, fig. 723.

electro-magnet, and p and q those for that of the revolving one. Even a single good Bunsen element—in the screws on which the wires from the poles are fastened so that one pair is connected with m and p, and the other with n and q—suffices to put the apparatus in motion and to lift about ¼ kilo. Two zinc and carbon pairs of elements with chromic acid will do about the same. If two good Bunsen pairs are used a very rapid rotation is produced, and about 2 kilos. can be raised. It is a good plan to make the supports of the fixed electro-magnet movable, to a certain small extent; for though the revolving electro-magnet, in its ordinary state, may pass freely between the poles of the fixed one, yet when the circuit is closed the latter is so powerfully attracted to the former that the surfaces of the poles of the two magnets impinge upon one another with a sharp blow. It is then necessary to push the supports so far back that the iron plate can revolve without any contact taking place. The kind of apparatus above described will give satisfactory results even if constructed on a smaller scale than that indicated.

MILITARY TELEGRAPHY.

The vast practical importance of the telegraph as a means of communication, in connection with military and other strategical manœuvres, has been thoroughly established by practice in recent years, in the French, Russian, American, Prussian, and Austrian Campaigns, as well as during the Autumn Manœuvres in England. In consequence its adoption into the standing armament of a nation's offensive and defensive arrangements for camp and field despatches has become a matter of imperative necessity.

The requirements of an efficient military or field telegraph are unlike those of the telegraphs in use for ordinary commercial correspondence. These requirements are:

1. Compactness and portability.
2. Rapidity and correctness of action.
3. Readiness at all times for immediate use, and possessing its own source of electrical power independent of liquid batteries.
4. Not easily deranged by rough usage or rapid transport.
5. The capability of being worked by any ordinary staff without previous training.

Without these essential requirements no telegraph is really trustworthy for military service. The difficulty of transporting acids and chemicals, the frequent absence of water in arid and sandy districts, and the evaporation that takes place in tropical climates, render the employment of voltaic batteries highly objectionable. The necessity of providing a trained staff upon which to rely for the working and manipulation of a telegraph when conventional signs, such as the "dot" and "dash" of the Morse alphabet, are employed, is also equally to be deprecated. The vicissitudes of military operations, the losses by fever, and the reprisals of war, may at times effect the sudden removal of the whole of a trained staff, and completely destroy the usefulness of any telegraph, to whose operation they are necessary.

A military telegraph, to be available, must be as equally effective for "rank and file" service, as when in the hands of the staff officer.

FIG. 7.

The military telegraph and "service" system, invented by Sir Charles Wheatstone, combines all these essential points, and is especially adapted for extremes of climate, and for correspondence by *cypher*, or in any language in which the words are expressed by alphabetical combinations.

The electric power is derived from a permanent magnet contained within the case of the instrument, a constant series of currents from which is obtained

by the continuous rotation of a small soft iron armature placed before its poles, and actuated by a handle in front.

The signals are given by the successive depressions of corresponding finger keys, arranged around a dial controlling the number and frequence of the magneto-electric currents, transmitted through the telegraphic circuit to the distant instrument. The depression of any one of these finger keys immediately releases the key previously depressed, and at the same time automatically regulates the space through which the pointer at the distant station has to move, in order to indicate the required signal.

The apparatus, is therefore, at all times in readiness for immediate use without any previous preparation; and so perfect is the mechanical construction, that messages may be transmitted with a rapidity exceeding *one hundred* letters or twenty words per minute over circuits of from one to two hundred miles in length.

By these arrangements neither a proficiency of skill nor knowledge is required; the operation of sending or receiving a message is purely mechanical, and restricted to the most ordinary rules of orthography; trained clerks are dispensed with, and the telegraph becomes available in the hands of unskilled operators. The apparatus is not affected by temperature, and will work equally well in hot or cold climates.

This telegraph is contained within a compact case, 13 inches long by 8 broad, and 7 inches deep, and the weight of the complete instrument does not exceed 25 lbs.

THE ELECTRIC LIGHT; AN IMPROVED AUTOMATIC PHOTOSTAT.

By HORATIO YEATES.

By a simple arrangement the battery current is made to regulate the distance between the carbon points, so that a steady and continuous light is maintained. It consists of an electro-magnet fixed at the top of a brass pillar. Across the poles of the magnet is a brass socket, A (Fig. 8), through which slides freely an iron bar, B, carrying the upper carbon point. The connection of this point with the battery is made through the coils of the magnet, so that when the current is completed by the points coming in contact, the magnetism excited in the electro-magnet holds the bar with the top point firmly in its place until the combustion of the points reduces the amount of current passing, when the magnet loses its power, and the bar slides down by its own gravity.

The battery employed with this photostat is a 10-cell Bunsen. The zinc of the battery should be connected with the screw marked z on the photostat, and the carbon with that marked c.

A second and more effective form of the photostat is that shown in Fig. 9. The brass rod which carries the upper carbon point slides freely through a fitting in the electro-magnet, and falls by its gravity when no current is passing. The armature, which is made in two pieces, has a space cleared away in the centre, nearly large enough to free the carrying rod, each half being supported by a brass spring at either side of the magnet, as shown in the engraving, and by them held in a slightly oblique position, and a little asunder, so as to allow the free motion of the carrying rod.

FIG. 8.

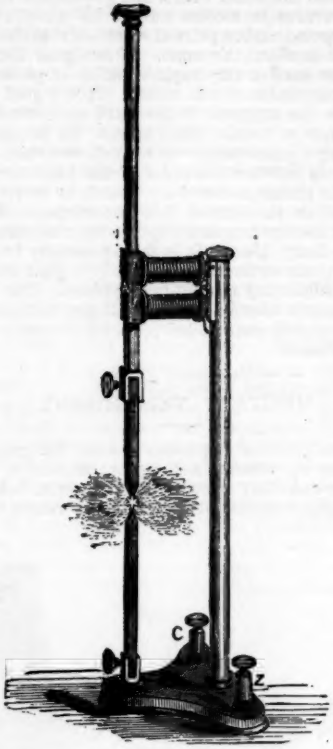


FIG. 9.

When a current passes through the wire on the electro-magnet, the two halves of the armature attract each other by the magnetism induced, and so close on,

and hold the carrying rod like a vice, but still leave a space between the armature and the poles of the magnet, through which the halves of the armature will be drawn up (still holding the carrying rod). The carbon points are thus more or less separated, according to the strength of the magnetism developed by the current. I am told that the photostat has been employed for five consecutive hours, giving at every instant during the time a perfectly steady light.

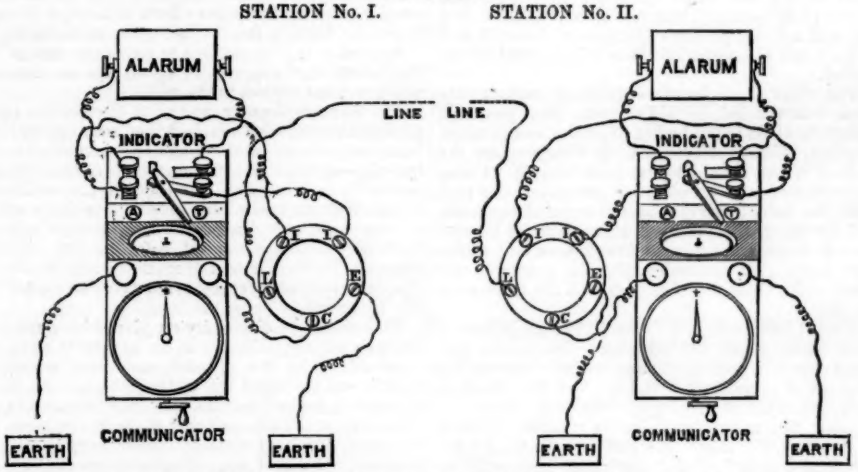
SIR C. WHEATSTONE'S SYSTEM OF DUPLEX-TELEGRAPHING.

In a recent number of this Journal there appeared an account of what had been done in the endeavour to transmit messages simultaneously, in opposite directions, through a single wire. At that time and since, the application had no beneficial result. Recently, however, experiments have been resumed on the lines of the Postal Telegraph Establishment, and under the able direction of Mr. R. S. Culley, C.E., the Engineer-in-Chief, they have been attended with practical success. It is now proved that by this means the working capacity of a single wire and of its instruments may be nearly doubled. In order to make Sir C. Wheatstone's A B C instruments also efficiently available for this purpose, a small supplementary apparatus has been constructed, which can be readily connected in the circuit of any A B C instrument, in order to render it a duplex-working apparatus. Besides the advantages of time-saving afforded by a system of duplex-working, operators find it particularly convenient, as it allows the receiver of a message at once intelligibly to interrupt the sender, in order to convey his desire for repetition or correction, without waiting for the end of a word; and with the alphabetical system it is out of the power of an unskilled operator to put his own indicator-needle out of place, as at present.

We subjoin a description of the method of connecting Sir C. Wheatstone's system. The supplementary apparatus consists of a circular case containing a series of resistances terminating at five connections, C, L, E, I, and I. The two upper screws at the back of the indicators are connected to the terminal screws, I and I, of the resistances in the way shown in the annexed plan.

The right-hand screw of the communicator at Station I. and the left-hand screw at Station II. are attached to terminals C of the resistances; the lines wire to terminals L of resistances; earth to E of resistances, and to the remaining terminals on the communicator. The alarum bells are, as usual, connected between the two lower screws at the backs of the indicators. When the apparatus and line wire are in order, the pointer of the indicator will not move when signals are transmitted by the communicator. If the earth connection be removed from E of the resistance, the duplex portion of the apparatus is put out of circuit; the whole current then passes to the distant station, and the indicator-needle moves, when the communicator is worked, as in the ordinary system of working. If the line wire be either broken or make contact with earth, the indicator-needle will move when the communicator is worked, but it will stop at the space before zero.

FIG. 10.



RUSSIAN TELEGRAPHY.—In January, 1869, the number of telegraph stations throughout Russia was 380, and the number of telegrams despatched in the empire of the Czars in 1868 was 1,491,834. In January, 1872, the number of Russian telegraph stations had increased to 648, and from these offices 2,860,649 telegrams were despatched during 1871.

WESTERN AUSTRALIAN TELEGRAPHY.—Progress is being made with a telegraphic line between Perth, Western Australia, and Albany, King George's Sound. A line from Perth to Bunbury is to be extended as far as Bassetton, the port and principal town of the Vasse district in Western Australia, and a new line from Newcastle to Geraldton, Champion Bay, is to be commenced in a few weeks. The jarrah posts for this line are to be supplied at a cost of £19 9s. per mile by Messrs. Smith and Nunan; the former of these gentlemen constructed the line to Bunbury.

Electro-Physiology.

The Action of Electricity upon various Organic Forms.

MM. Robin and Legros, experimenting with *Noctilucæ*,—those little organisms which produce in great part the phosphorescence of the sea,—found that, on passing a current through some sea-water in the dark, its course was marked by a luminous trace, the phosphorescence of the animals being excited by the electricity.

Induction currents retard or arrest the circulation, by contracting the blood-vessels. Continuous currents, however, generally have an opposite effect. MM. Onimus and Legros have further established the law, that a descending current dilutes the vessels, while an ascending current contracts them. Part of the cranium of a healthy dog was removed; the positive pole of a strong pile connected with the brain, the negative pole with the neck. The superficial vessels of the encephalon were visibly contracted, and the organ appeared to be weakened. On reversing the position of the poles the opposite effect was observed. By means of an ophthalmoscope the fine blood-vessels on the retina of a living person's eye may be observed, and if the head be electrified these will be visibly distended.

The effect of an electric current on bodies newly dead was studied by Aldini, who thus produced violent motions in the bodies of guillotined persons. Similarly Ure experimented, in Glasgow, on the body of a man that had just been hanged. Using a battery of 270 couples, he connected one pole with the spinal marrow at the nape of the neck, and the other with the heel, whereupon the leg was moved so vigorously as to knock over one of the attendants. He succeeded, also, in producing motions in the chest, the abdomen, and the features of the face.

Recent research has defined the conditions of such influence on the muscles. Continuous currents, applied directly, cause contractions at the moment of opening and closing; but the shock on closing is much the stronger. While the current is passing the muscle remains in a state of semi-contraction, the nature of which is not agreed upon by physiologists. Under excitation frequently repeated, and prolonged a certain time, the muscles get into a state of contraction resembling that in tetanus. While in this state they are in constant minute vibration.

Induction currents cause more energetic contractions, but this energy does not last long, and, if the electrification is continued, gives place to cadaverous rigidity. In both the foregoing cases there is a local elevation of temperature, proportional to the force and duration of the electric action. This reaches its maximum (sometimes 4°) in four or five minutes after the electric action has ceased. The muscular contraction disengages heat.

The action on the nerves is more complex. MM. Onimus and Legros state that, in the case of motor nerves, the direct or descending current from a battery acts more energetically than the other, the reverse being the case with the sensory nerves. The sensation experienced in these cases (which refer to continuous currents) is insignificant; induction currents, on the other hand, produce a pain, which continues to be felt so long as the nerve retains its excitability.

If a frog is kept some time in tepid water at 40° it dies. If then taken out, and its spinal cord electrified by an ascending current, vigorous contraction ensues; a descending current produces no motion. On the other hand, if the latter be applied to a decapitated animal, in which reflex motions are being caused by the excitation of the spinal cord, it tends to paralyse them.

In general, the battery current applied to a cord, if an ascending one, increases the excitability of this organ, and therefore its power of causing reflex action; the descending current acts in the opposite way.

When the brain is electrified the animal does not give signs of pain, but of calm stupor and tendency to sleep. Some have proposed electrification as a means of developing the intellectual faculties; but there is no evidence that it will thus act. On the other hand, extreme care is necessary in electrifying the encephalic parts, as a strong current may produce rupture of the vessels and serious hœmorrhage.

Electricity stimulates all the other organs of sense, producing luminous effects in the eye, sound in the ear, taste in the tongue, odour in the nose.

Applied to the nerves of the nutritive organs, it has the effect of suppressing spasmodic movements which are not subject to the will.

The German theories as to the electrotonic properties of the nerves when electrified were opposed by Matteucci, who urged the obvious phenomena of electrolysis,—that is to say, the chemical decompositions caused by the currents. He thought the modifications in nervous excitability produced on the passage of electricity were due to acid and alkalies arising from the decomposition of salts in the animal tissues. To this class of phenomena may be added the electro-capillary currents recently discovered by M. Becquerel.

The effects of electricity on plants have not yet been so closely studied. It is known to produce contractions in the *Mimosa* and other sensitive plants, and to retard the motion of sap. M. Becquerel has studied its influence on germination and development. It decomposes the salts contained in the seed, the acid elements being carried to the positive pole, and the alkaline portions to the negative. Now, the former are hurtful to vegetation, while the latter favour it.

M. Becquerel has, further, quite recently examined the influence of electricity on the colour of plants. The discharge from a powerful machine produced remarkable changes of colour on the petals, due, he thinks, to the rupture of cells containing colouring matter. Deprived of this cellular envelope by washing, the flower becomes white.

Electricity as a Means of Resuscitation.

Allan M'Lane Hamilton, M.D., New York (*Am. Practitioner*, Oct., 1872), in a paper on this subject, speaks of the following results, arrived at from his own practice and experiments:—(1) That it is useless to expect good results if five minutes have elapsed since life appears extinct; (2) That the current should be applied faithfully and steadily, one pole being placed on the ensiform cartilage, the other on the base of the skull or over the tracks of the great nerves of the neck; (3) That the

Faradic and interrupted galvanic currents are the best; (4) That the current should be applied some time after respiratory movements have become regular. In concluding, the author says, "The necessity of having a battery within reach is apparent. Every practitioner should have a small one for emergencies. They should be kept at each life saving station on the coast, ready charged, with directions for immediate use. If this were done, he doubts if the percentage of deaths would be so great as it now is. Artificial respiration, by the production of muscular movements, is a very valuable means of restoration; but a force that acts directly upon the nerves, supplying the muscles of respiration, is by far the surest and best."

Water not an Electrolyte.

In the face of the statement that the physiological effects of the current are due to electrolysis, it becomes interesting to study the researches of M. Burgoin, by which he seeks to prove that water does not possess electrolytic properties. It would, of course, be premature to offer a decision. M. Burgoin states that books have long taught that the object of adding an acid, in the electrolysis of water, is to render it a conductor. The fact that compound substances when decomposable conduct only by electrolysis; and, hence, that a body not an electrolyte cannot be made so by the addition of another body, has long rendered it probable that it is the acid which is actually decomposed by the current, and that the water suffers decomposition only by a secondary action. Bourgoin has investigated the subject experimentally, and has proved that water is not itself an electrolyte.

His apparatus consists of a cell, divided into two equal compartments by an impermeable septum, which septum is pierced with an opening so minute as to prevent any mixing of the liquids on its two sides, while yet it allows the passage of the current. The cell is so arranged that the gases evolved from the electrodes may be collected and measured. Both compartments are filled with water acidulated with sulphuric acid, and the current is passed for a given time, the hydrogen being collected. When the experiment is concluded, the contents of the compartments are separately analysed. Under these circumstances it is found that, in the positive compartment, the acid has increased in amount by a certain quantity, a, while in the negative it has diminished by the same amount. The quantity of sulphuric acid decomposed is then equal to $2a$. But this quantity of acid can furnish only a third of the hydrogen obtained; or, calling P the weight of the hydrogen measured, the acid can yield a quantity of hydrogen equal to $\frac{P}{3}$.

It is therefore certain that it is not H_2SO_4 which is decomposed, but $H_2SO_4+(H_2O)_2$, or H_6SO_6. Two hypotheses may be offered to explain this result:—(1) Both the water and the acid are decomposed by the current but successively:—

	Positive electrode.		Negative electrode.
$H_2SO_4 =$	$(SO_3+O)+$	... ...	H_2
$(H_2O)_2 =$	O_2 +	... ...	H_4,

or (2) The current decomposes a definite compound having the formula—

$SO_3(H_2O)_3$, or H_6SO_6:

$H_6SO_6=(SO_3+O_3)+$ ... ... H_6.

Facts show the second supposition to be the true one. Operating, for example, with currents of varying intensity containing different proportions of acid and water, from H_2SO_4+3 aq. to—

H_2SO_4+125 aq.,

it is found that the ratio of the acid decomposed to the hydrogen evolved is always that above given; which would not be the case, in all probability, were the acid and water separately electrolysed. Moreover, the compound H_6SO_6 is not a hypothetical one, since an acid of this constitution has been rendered probable by the maximum contraction observed when 1 molecule of H_2SO_4 and 2 of water are mixed. In the case of nitric acid, the action of the current appears to be upon the group $N_2O_5(H_2O)_4$; a body conceded to exist. Crystallised oxalic acid, fortunately, when in solution, is electrolysed alone, no water taking part. The hydrogen disengaged corresponds to the equation—

$C_2H_2O_4(H_2O)_2=(C_2O_4+O_2)+$ ... ... H_2).

As only carbonic dioxide is set free at the positive electrode, it must be that the oxygen evolved reacts upon and destroys another portion of the acid, thus—

$(C_2H_2O_4(H_2O)_2)_2+O_2=C_2O_4)2+H_2O_6)$.

Moreover, if this interpretation be true, the quantity of acid destroyed should be much greater at the positive than the negative electrode; for—

Acid destroyed { (1) At N electrode. By current 1 mol.
(2) At P electrode. { By current 1 mol.
By oxygen 2 mols.

Now, experimentally, the loss of acid at the positive electrode is exactly three times greater than at the negative. Again, in electrolysing formic acid, only carbonic dioxide is disengaged at the positive electrode. Three hypotheses may be offered to explain the result:—(1) The current acts on the acid only, thus—

	Positive electrode.		Negative electrode.
$(CH_2O_2)_2=$	$(C_2H_2O_3+O)+$	... ...	H_2,

and then at the positive, the further reactions occur—

$C_2H_2O_3+O=CO_2+CH_2O_2$.

(2) Water alone is decomposed—

$CH_2O_2+O=CO_2+H_2O$,

and (3) The acid and the water are both decomposed simultaneously—

$(C_2H_2O_3O)+O=(CO_2)_2+H_2O$.

If a represent the amount of acid electrolysed, the loss will be—by the first hypothesis, nothing at the positive and equal to $\frac{a}{2}$ at the negative electrode; by the second, on the contrary, there is no loss at the negative, and the loss is equal to a at the positive electrode; and by the third, it is equal in each compartment, being represented by $\frac{a}{2}$. Now, experiment shows that there is no loss of acid at the positive electrode; hence, the first hypothesis is the true one, and the water is not decomposed by the current. The same general results were obtained in the electrolysis of alkalies and salts. Bourgoin concludes, therefore, that: "Water is not decomposed by the electric current; it plays the part of a solvent only."

Communication by cable between Dominica and Martinique is interrupted, and a vessel has been engaged to carry the despatches between those islands.

Proceedings of Societies.

SOCIETY OF TELEGRAPH ENGINEERS.*

February 26, 1873.—Latimer Clark Esq., C.E., in the Chair.

Discussion on Telegraph Poles.

The Secretary read a communication from Mr. Haynes, Superintendent of Telegraphs on the Bristol and Exeter Railway, in which he expressed his opinion that iron sockets preserved poles twice as long as when they were put into the ground in the ordinary way. If foreign creasoted timber were used, it was as good a material as could be desired, but there was a difficulty in getting poles properly creasoted. The subject of creasoting was one which was worthy of some attention.

Captain Mellor stated that in 1850 the first telegraph lines in India were erected with wooden poles. These were found to rot in the ground, and cast-iron sockets were used. Various experiments were tried with galvanised iron tubes, the idea of wooden poles in an iron base being still adhered to; and it was not till 1864 that it was ascertained that the best poles were made completely of iron. They were thus a year behind the introduction of iron posts on Mr. Siemens's patent of 1863. From 1864 the next lesson was, that iron posts must be such that, whilst having one general character throughout the line, they would vary in details according to situation. They were not allowed in that country to put the line within 24 feet of the rails of a railway, and were thus driven sometimes into very bad ground. With reference to base plates, there were many soils in which they were not required. Those in use in India varied in diameter from 22 to 26 inches, with a depth of from 3½ feet to 6 feet.

Mr. C. W. Siemens said that the paper which he had read on the last occasion was not intended to be anything more than a simple statement of facts regarding the construction of posts which he had introduced many years ago, by way of addition to information to be furnished to the Society by Major Webber. He had hoped that Major Webber would bring before them the construction of posts of different kinds, in order that they might be benefitted by his investigations, and he was somewhat disappointed to find that he had confined himself to criticisms of the existing constructions, and a sort of *resumé* of what was being done. There were several points on which he dissented from Major Webber. Twelve years ago his attention was turned to the necessity of iron posts in countries where wooden posts were subject to dry rot. Two or three years seemed to be the life of wooden posts in South Africa and South America, and though they might be creasoted, that did not materially prolong their life. The necessity, therefore, became evident for a post of greater durability, and the question then arose as to the best form in which to put iron, in order to support the wire at a given height. After many experiments, he concluded that a conical tube would be the best, but in going minutely into the matter he found that there was one particular proportion between the diameter of the tube and the thickness of the metal which gave the absolute maximum of strength. He did not agree that telegraph poles might be constructed to suit the individual fancy or requirements of an engineer; the construction of them was, perhaps, one of the most definite things in engineering, and could be once for all solved in a perfectly mechanical manner. He (Mr. Siemens) found that the lower portion of the post, which was exposed not only to the strain of the wire but to the moisture of the ground, had to be of a different material. Then came the next question, how was the post to be fixed. The natural suggestion was to make a hole deep enough and put the post in. You had a post very small in diameter, necessarily, because it was limited in weight, and constructed of a material of greater density, and you would therefore require to put an iron post deeper into the ground than a wooden post. Major Webber put his iron post 6 feet into the ground, and the claim in favour of that construction over the base plate such as he (Mr. Siemens) proposed, was that it lessened the base and caused a saving of material. The only difference would be, that his pole would be 2 feet 8 inches deep, and Major Webber's 6 feet; so he thought he had the advantage there, and there was a saving in absolute weight of 54 lbs. It was an advantage of the base plate that the weight of itself fastened the post, and he was strongly for maintaining it as an important feature in the construction of posts. By being able to carry the post in three parts various conveniences were gained.

Colonel Robinson gave illustrations of various forms of poles which were in use for telegraph purposes in India.

Mr. Graves said that with reference to the main question of iron *versus* wood, he was afraid he was sufficiently purblind to see it through only one medium at present, viz., that of comparative cost. In this country he gathered that iron poles, however recommended on mechanical grounds, were decided to be much more costly than wood.

Mr. Culley said that the meeting might perhaps like to know why he did not use iron poles. Iron poles, he believed, cost about three times as much as wood, and therefore he looked at the matter very much through the same spectacles as the last speaker. He used wood simply because creasoted wood would last a very long time, and the only cases where iron was employed were in those localities where people objected to the telegraph unless it was carried through on iron poles. The public were very much led away with respect to telegraph poles as they were with respect to jewellery and ornaments. A thing might be beautiful and yet be despised if it was cheap, but if it cost a good deal it was admired. People, he believed in a great measure, preferred iron poles because they cost more than wood. He must make an exception as regarded the specimen of pole produced to the meeting, which was certainly prettier than anything they could make of wood. Without going into the mechanical merits or demerits, he might have an opinion, perhaps, that iron poles would be liable to rust, and would not last very long, but he was afraid that if this pole were generally known they would have orders to take down the wooden poles from half the towns in England and put up such as that, because people would have ornament. For his own part he should prefer something that was more correct from an engineering point of view than one that was ornamental. When he said that iron poles cost three times as much, he was, of course, speaking of the first cost. The poles which had been placed in iron sockets were found to last very well—perhaps twice as well as the others—where the socket had been well above the ground, and the pole had been well fitted into the socket. If the water got in, the pole rotted quickly. Creasoting seemed to preserve wooden poles for a very long time. In fact, as yet, no creasoted telegraph poles had gone, but it was only fair to say that his experience with them had not extended over many years. He thought, however, there were some fourteen or fifteen years old. As to the coppering process, it answered pretty well, though not so well as creasoting. The cost was about the same, but if the impregnation of the particular pole happened to be badly managed, as was the case occasionally even with the greatest care, the timber would last a much less time than other timber. In 1862-3 he was concerned in the preparation of some six and seven thousand poles which were subjected to this process. One difficulty con-

* Reported, with the consent of the Council, for this Journal.

sisted in finding timber suited for the purpose, which was open-grained timber with little heart, so that it might be thoroughly impregnated. In some cases timber was too old, and though the poles were kept from three to four weeks under pressure, the process was useless. In the neighbourhood of Huntingdon and Peterborough, where the soil was almost purely peat, some poles which had been fairly put through this process were showing symptoms of dry rot to such an extent that it was necessary for them to be removed.

Major WEBBER said that when it first entered his mind to write a few remarks on the application of iron to telegraph poles, he was not aware that Mr. Culley was going to investigate the subject as to the best means in which iron could be applied, and he therefore had proposed to enlarge upon the subject instead of giving a mere *resumé*, as Mr. Siemens had justly stated; but when he found that the subject was becoming of such moment that the Post-Office was going to investigate it, his mouth was, to a great extent, shut as to any opinion which he might give with regard to the pole of the future to be used in this country. Mr. Siemens could not agree with him on the expediency of his proposal for iron poles to be terminated at the lower extremity with a base plate. This plate, it was shown, existed already in the case of a large number of poles used in various countries. Now, he was perhaps very bold in saying anything more on this subject, but he wished to concede more to the principle of applying the base plate than he did in his paper. Mr. Siemens did not mention the probable weight which that plate carried. If we took the weight as represented by a tube equal to 2 feet 8 inches, we should get a mass equal to 8 cwts. But he would go farther, and say that this plate was kept down by a mass which was equal in area to double the size, or four times the size of the area of the plate. The upward pressure of the pole extended to a distance of 2 feet 6 inches on each side, and including an area of 5 feet square, this would give a weight of 1½ tons, particularly if the earth were piled up around the pole, as shown in the drawing. But there was one point which he must advert to, and which seemed to have been missed. In his paper he said he doubted the expediency of applying a base plate to a pole which had to deal with such forces as those he had described. These forces were very different from those acting on a tree. The tree which fell easiest was the tree which had no depth of root, but in which the root spread out and covered a large area at a limited depth below the surface. The trees which stood best, like the oak, were those in which the roots penetrated deeply below, and probably to a depth equal to the height of the trees above the ground. The tree, however, was not a telegraph pole, and had not to do the work which a telegraph pole had to do. For instance, the tree had only to resist the shocks it received from the wind, and when the storm was over the ground in time became consolidated over the roots, and the tree was as firm as ever. The pole had to resist a constant strain in one given direction, and, hence, the difference in the two cases. Mr. Siemens had said that the pole in his case saved in weight below the ground. That was entirely a question of where the point of fixture should be. In that pole the point of fixture was evidently on the base plate, but in the pole which he (Major Webber) described, the point of fixture was close to the surface. Mr. Siemens, in advocating the base plate, had mentioned that the iron pole being smaller than the wooden pole, a smaller surface pressed against the ground, but the answer to that was, that no one would ever think of leaving the pole in such a position as that the section of the pole itself was the only resistance. We should have to put in a long rigid surface in the shape of a stone, &c., against which it would rest, and to which would be communicated the whole of the pressure. Then, as regarded the amount of earth to be taken out for a pole going 6 feet into the ground, it was quite true that it would be 17 or 18 cubic feet, but then he maintained that this ton-and-a-half of earth would not be able to keep a base plate down so that the pole would remain perpendicular when subjected to severe horizontal strain, such as he had referred to in his paper; whereas by using such ordinary appliances as everybody knew of, you could make the ground hold the weight and resist the strain if the pole was only strong enough.

Mr. SIEMENS, in reply to an enquiry with reference to the strength of the joint at the base plate, as to whether the base plate would raise the whole superincumbent mass of earth, said the strain applied at the top would bend the whole pole over to such a point as to approach the ultimate strength, and then it would be a matter of accident where it would break. Most likely it would break near the ground-line of the cast-iron. There was an advantage, he believed, in the base plate being flexible, that it saved the pole from giving way at the joints. It would begin to yield a little, and if the ground was not firm, possibly it might be serious; but that was the most difficult point. It would be useless to make the pole firmer in the earth than it was above the earth.

The CHAIRMAN said he much regretted that Major Webber had not favoured the Society, in his interesting paper, with his views as to the best form of pole which he should adopt if the matter were in his hands. Lieut. Jekyll had furnished some diagrams which would be of very great use to telegraphists in their calculations. Mr. Siemens had read a very valuable paper, and had described fully the pole which he proposed, and which had advantages in two or three points in common with those used in India. A combination of cast-iron at the base with wrought-iron at the top was undoubtedly good. With regard to the base plate, he must say his feelings were entirely with Major Webber. It necessitated a very great strength of pole at the lower part. He was surprised that no one had alluded to the advantages of making a pole stronger in one direction than another. His idea of a pole was, that there should be something to give greater strength laterally than in the longitudinal direction of the line. Mr. Lee had shown a very elegant pole, but had not made any observations upon it. He presumed it was not intended to put that in competition with Mr. Hamilton's or Mr. Siemens's, but that it should only be used in special cases. The best form of pole seemed to be one very much like Mr. Siemens's, consisting of a long cast-iron base, with a wrought-iron taper top, but with the tube strengthened by a rib on each side. The use of the screw for screwing in, as it was called, was decidedly advantageous. There was no necessity for digging a large hole and loosening the pole, but such a pole could be screwed down in the earth very firmly by only taking out a sufficient amount of soil at the top to enable the pin to be fixed in it. He wished they could have had more information upon this important subject, but he congratulated the Society on having had a very interesting discussion. This might be considered the Anniversary meeting, the first having been held on the 20th February last year. They could all congratulate themselves on the very satisfactory progress the Society had made. In point of funds (which were certainly very important in all matters in this world), they were well off, and in point of numbers the progress had been very considerable. At this time last year there were 110 members of all classes, and at the present moment there were 409 (Applause).

A vote of thanks to Major Webber, Lieut. Jekyll, Mr. C. W. Siemens, and Mr. Robert Bristow Lee for their papers concluded the proceedings.

An ordinary meeting was held on Wednesday evening, the 12th inst., LATIMER CLARK, Esq., Vice-President, in the chair.

Three communications from Mr. STOUT, of Lerrick, on "*Earth Currents*," were read by the Secretary. In the first paper the writer stated that he has often had the needle of his instrument vibrated by accidental or earth currents, and sometimes to such an extent that it was impossible to continue working even with a single needle instrument. These currents seem to be the strongest when there is a considerable aurora, but sometimes there is a brilliant aurora and very little current or none at all. He had observed that upon a shower of snow coming on, the currents commenced, that they increased in intensity until the storm was thickest, that they lessened as the storm subsided, and disappeared when the shower ceased. This was more noticeable when the snow came in large fleecy flakes. Hail did not seem to have any effect on the currents. The two other communications stated the results of observations made on the occurrences of aurora and their relation to earth-currents.

Mr. G. K. WINTER, F.R.A.S., read a paper on "*Earth Currents*." The author stated that the electric telegraph had been but a short time in existence when it was found that occasionally very powerful currents from some unknown source showed themselves in the wires. Happily these disturbances were found to be neither of very frequent occurrence nor of long duration. Subsequently, however, as more delicate instruments were used, it was discovered that the wires were scarcely ever free from the currents, and though they were rarely strong enough to interfere seriously with speaking instruments, yet they considerably embarrassed testing operations. The author has for many years given these currents a good deal of attention, and although his experiments are as yet very far from being complete, he thinks that some of the results already obtained are of some interest; and as the methods he has adopted are in some respects novel, a few words on the subject might not be unacceptable. He commenced by assuming that the currents in the wires are due to large streams running through the earth, and that the strength of the current in any one wire is influenced by two circumstances—first, the strength of the earth-stream, and, secondly, by the angle it makes with a line joining the two earth-plates. Of course the resistance of the circuit and the distance between the two earth-plates have their influence. Their effect may, however, be looked upon as practically a constant factor for any one wire. The variation of the current in any one wire must be attributed to variations in the circumstances above mentioned. The object of his experiments was to determine the two influences separately. By making simultaneous observations on two wires placed at right angles to each other the separation becomes very easy. The experiments were made near Madras. Two wires were erected, each two miles in length, and approximately of the same resistance, one running north and south, and the other east and west. The instrument used for measuring the current was a tangent galvanometer. Right and left deflections were taken, and the mean of the two was calculated. The currents of both wires were observed on the same instrument. The whole of the changes were made by a very simple series of switches. The observations occupied about one minute, and were reduced in a very simple way. The method adopted was simply an application of the principle of the parallelogram of forces. It is scarcely to be expected that the stream is uniform in its strength, direction, and variation in different parts of the world. The apparatus for the measurement of the two elements of the currents need not be of an expensive character. There are doubtless numbers of people in different parts of the world who are qualified to make observations. Of course it was necessary for proper organisation that the matter should be taken up by some scientific body, and that definite directions for observers should be drawn up. The author believes the absolute magnetism of the earth to be much more constant than is imagined. A more practical bearing of the question is the effect of the derived currents on our tests, and the best means of eliminating errors likely to arise from them. The author has already treated this question at some length in the *Philosophical Magazine* for March, 1872. It is the variation and not the existence of the earth-current which is the source of the chief difficulty, for as both the electromotive force and the resistance are unknown we require two observations to enable us to determine either; and it is difficult to make two observations so quickly one after the other as to ensure the constancy of the earth-current during the interval. Mr. Mance has described one method, and the author has pointed out another, in which one observation is simply noting the deflection, and the second seeing that this deflection remains the same after making and breaking the contact with the key. The object is to give the earth-current no time to vary. The method proposed by the author was described in his paper in the *Philosophical Magazine*, and is simply a modification of Mr. Varley's method of measuring a single cell by means of a differential galvanometer. The difficulty arising from the sudden flow through the galvanometer is common, in a greater or less degree, to both Mance's method and that described by the author. One way in which he proposes to remedy this is the use of a condenser. The author concluded a lengthy paper by recommending that the Society should take up the systematic investigation of the subject of earth-currents.

A communication from Mr. J. M. Graves, of Valentia, detailing a series of minute observations on the same subject, was read by the Secretary. The paper was accompanied by various illustrative tables.

Mr. VARLEY said that Mr. Barlow was the first person who made any systematic record of earth-currents. He began in 1846, with the assistance of one of the Vice-Presidents, Mr. Culley, and used the wires of the Midland Railway for his observations. A record of these would be found in the *Transactions of the Royal Society*. He found that the strength of the current was by no means proportional to the length of line in circuit, but depended upon whether the direction of that line coincided with the direction of the earth-current; that there were periods of maxima and minima; that there were always earth-currents on the line; and that these earth-currents were not disturbed by auroral currents, which were very erratic. In 1847 he (Mr. Varley) observed the first earth-current which it fell to his lot to see. It was on the occasion of a tremendous auroral display, in which the arch was distinctly visible above the horizon for several degrees, and all the lines in Great Britain were stopped for the time being. That was the first time that attention was strongly drawn to the subject, and the question was taken up by the Astronomer Royal, Mr. Airey. Mr. Walker and the Astronomer Royal had now been making observations by means of cross wires for more than twenty years, and had drawn out the true direction of the currents upon the principle of the parallelogram of forces which Mr. Winter had described. It was well to observe that if experimenters used an earth-plate of limited size its resistance would vary a good deal, owing to the hygrometric condition of the earth varying, and other causes. If they attempted to get a very large earth-plate by connecting the wire with the gas-pipes, then they would get not only the current due to the wire itself, but also that which was due to the extensive system of pipes with which it was connected. In

1855 he observed, on a line of only 2 miles length, a current so strong that it stopped the working. The enormous strength of the current on so short a line led to some astonishment; but he thought that there was no doubt that the earth-current was not one that was the potential of the difference between the two lines of wire, but arose from the conductors afforded by the gas-pipes. In 1847 he observed an earth-current between Dawlish and Teignmouth, a distance of 3 miles, and in endeavouring to measure its potential he found that twenty-four cells of a sand battery were insufficient to balance it. From 1852 onwards he had kept very careful records at telegraph stations of all the earth-currents he could observe, and some very curious results had been obtained. First of all, he found that there were certain localities between which the currents were strongest; the strongest of all being between Ipswich and London. Ipswich might be considered as a sort of funnel-shaped indentation of the coast. Off King's Lynn there was a similar funnel, and this place was not far north of Ipswich, and yet the currents from the former place were very feeble. But farther north, from Newcastle for instance, they got the same earth-currents as were generally got from Ipswich, which was at the southward of King's Lynn. It was frequently found that while the currents from Newcastle to London, and Ipswich to London, were positive, that from King's Lynn would be faintly negative. On drawing the neutral line it became evident that that neutral line very nearly followed the line of the coast; and that was most likely due to the circumstance that arable land, as compared with sea water, was a very poor conductor, and consequently the currents observed on this particular land line were those brought by the sea, arrested in a great measure by the non-conducting land. If observations were made simply on such currents, it would not be right to infer that the general current of the year was all the strength indicated upon the line. It would be very much feebler, the concentration being due to the great currents of the whole earth being arrested by the less conducting land. This was borne out very strongly by the fact that the currents observed from Amsterdam to London, which were almost in the same line as Ipswich and London, but 130 miles farther apart, were but little stronger than the currents from Ipswich to London. He had frequently endeavoured to measure the earth-currents on short wires. In his garden he had a number, varying in length from 200 to 600 yards, and laid in different directions; but he found that the variations, due to the different states of moisture and other conditions, were so great that the earth-currents could not be recorded with any certainty. In fact, he knew of nothing more difficult than to get two earth-plates, in different parts of the earth, neutral to the earth or of equal potential. In the first paper attention was drawn to the fact that the earth-currents varied very much with the snow. He was afraid that Mr. Stout had mistaken the cause of that variation. The changes had probably been due to the snow producing increased leakage between the wires and the earth, by connecting the wires with the poles, or, possibly, with a wall. The rapid variation of the earth-currents which Mr. Stout had observed he (Mr. Varley) thought must be due to some station endeavouring to call, and not to the earth itself, for he had never on any one occasion found an earth-current to change from maximum positive to maximum negative in less than 50 seconds. More generally the change occupied several minutes, and once he saw a continuous current of twenty minutes' duration. In November and December, 1867, he took a number of observations on the Rigi with reference to the existence of the so-called negative cloud. He did once observe a negative cloud of 400 cells power during a snow-storm, but the atmosphere above was negative for only an hour and a half, and it then resumed its normal positive condition. He mentioned this because it would be interesting to ascertain whether the formation of snow really influenced the electrical conditions of the atmosphere. The subject of earth-currents had often caused him very serious doubts as to the existence of long cables. When the 1865 cable broke, after 1200 miles had been laid, a series of very powerful earth-currents showed themselves, and Mr. Graves, who was then at Valentia, stated that so great was their power that they produced a distinct arc across his key over a distance of one-tenth of an inch. He (Mr. Varley) could not assume that the power could have been less than 2000 cells of Daniell's battery. He had frequently seen, between Ipswich and London, a difference of from 70 to 150 cells. When Admiral Fitzroy was establishing his signals, he (Mr. Varley) observed on two occasions that earth-currents were followed by a change of weather. This fact was communicated to the Admiral, and proved of so much value to him that for some time he had information of the earth-currents regularly supplied to him. It was often possible, by their means, to predict a coming storm before the barometer became affected. The subject of the difficulty in testing arising from earth-currents was a very important one. He and Sir Wm. Thomson had found, in testing the 1866 Atlantic cable, that one of their chief difficulties was to find a satisfactory method of eliminating the earth-currents. The method of testing adopted with the long cables made by the Telegraph Construction and Maintenance Company, since 1865, had been what was known as the slide resistance coil. In order to get the true reading, all they had to do was to take the slide reading first with the positive current, then to take the slide reading with the negative current; add the two together, and divide by two. The mean slide reading would be the correct one, and the earth-current would be eliminated. Mance's method of measuring resistance was a very pretty one, and was probably known to all present; but there was a very serious objection to its use. Every time they altered the resistance to get the true reading they altered their zero, and unless the coils were constructed specially for each case the amount of variation in the zero was very much greater than the amount of variation due to a very considerable error in the adjustment of the resistance coils; and the consequence was that, in measuring a long cable, each time they shifted the zero they must wait at least 15 seconds, for the cable to get balanced, before they could get another reading, and thus the observation was so protracted that practically they could not get a reading at all. As to the use of condensers, if Mr. Winter would refer to a paper published by him (Mr. Varley) in 1860, he would there find the whole thing delineated. There was, however, another way of applying Mance's method, and it was less liable to the objection of the zero shifting so tremendously. At St. Pierre, last year and the year before, when the cable was broken, Mr. Gott adopted the method of putting in a condenser, making an artificial line to facilitate the testing. That answered exceedingly well, and all that Mr. Winter had said about it had been borne out in practice. The Atlantic cable ran nearly east and west; and he very frequently found, on looking over the tests which were made almost every morning, that, although St. Pierre and Brest were nearly of the same potential, there was almost always a current through the gutta-percha in that direction, or *vice versa*. That is to say, the middle of the ocean was positive or negative to the two ends, while the two ends were pretty nearly of the same potential. Mr. Willoughby Smith informed him that on one occasion he could distinctly trace a current coming through the gutta-percha, and running across between the 1865 cable and the 1866 cable. This was indicated by galvanometers at each end showing a

similar current running in each direction. This confirmed what he (Mr. Varley) had repeatedly observed on the French Atlantic cable. He had very little doubt that the aurora was due to the discharge of electricity from the upper regions of the air to still higher regions; and the question arose, Whence came this electricity of the atmosphere? He thought it would be found to be due to the rotation of the earth. It was well known that when the atmosphere in a tube was reduced from the present pressure of about 30 inches of mercury down to 100th part of an inch, it had a conductivity, roughly speaking, as 5000 cells to 300, or say 200 to 1. To get such a reduction in the atmosphere, we must go up between 20 and 40 miles. The air at this height would not rotate so rapidly as the earth, and might therefore be considered as stationary to the earth. We had, therefore, a magnet rotating inside a fluid conductor. Faraday had shown putting the earth in rotation as it is, in its present direction, we should have the two poles positive the equator. He (Mr. Varley) believed that that was the source of the electricity of the atmosphere, because it was invariably found that the wind coming from the north pole was strongly electro-positive to the earth, and the aurora borealis generally occurred when the northern wind was coming.

Professor AYRTON said that in India a systematic attempt had been made to measure earth-currents by always making the tests with positives and negatives, and then calculating the electromotive force of the natural current. The calculation, however, was based on the assumption that the current flowing through the line was uniform, or produced by a certain difference of potentials at the two ends, namely, Allahabad and Calcutta. But, as Mr. Varley had pointed out, there might not be a gradual fall of potential from Allahabad to Calcutta. There might be a current flowing towards Allahabad observed at Allahabad, and a current flowing towards Calcutta observed at Calcutta. This rendered it difficult to tell how the electromotive force producing the two currents was distributed. One thing, however, the tests had shown in an isolated case which he remembered. In the beginning of February, 1871, he found out that there were many strong positive currents flowing from south to north on about eight important lines in India—those going through central India near Jubbalpore and Nagpore, and along the east and west coasts. The currents varied from 40 or 50 cells to 4 or 5 cells. This disturbance was followed on the next day by an earthquake. The really important and difficult point in connection with this subject was to find out how the electromotive force was distributed.

Mr. WINTER, in reply, said that he had listened with very great pleasure to the observations of Mr. Varley. He agreed with him as to the time taken in the reversal of an earth-current. Mr. Varley had said that in Mance's method the zero was altered on each adjustment. If the two proportional resistances were kept the same, of course that would be the case; but Mr. Mance had avoided that altogether by leaving the bridge entirely unaltered, and simply making his adjustment by moving the shunt. As to the artificial cable, he (Mr. Winter) did not know that it had ever been applied to testing before. With regard to the rotating magnet, Ampère showed pretty fully that the current generated by a rotating magnet was generated in the conductor, which did not partake of the same rotation, and was not generated in the magnet itself. In order to have a current from a moving magnet, you must have a conductor outside which did not partake of the motion, and which, in fact, remained still. At all events there must be a relative motion between the conductor and the magnet. If the conductor moved with the magnet, there was no current. But it was difficult to say, in the case of the earth, where there was a conductor which was not moving. Of course the winds were moving to a certain extent; but he did not think that that was at all sufficient to account for the immense difference of potential which must exist in order to cause the effects which were called the Aurora. Those shocks which Mr. Varley last spoke of he had noticed very particularly; and he also noticed that they were entirely remedied by the use of the induction coil instead of the condenser. The magnetic inertia of the iron apparently absorbed the shocks, and when, instead of the condenser being in circuit, the induction coil was in circuit, and the secondary currents were used to work the receiving instruments, all the shocks disappeared.

The CHAIRMAN said that they had had three very valuable communications. Mr. Stout, in his communication, made a suggestion which he (the Chairman) made himself in print some years ago, which was, that the varying earth-currents which were visible during an aurora might be caused by the induction of the flashes of auroral light as they appeared overhead, and many observations which he had given seemed to confirm that view. The same writer made a suggestion that snow-storms might have some effect in producing currents, as if the currents were derived from the air itself, and not from the earth. He (the Chairman) agreed with Mr. Varley in thinking that in that point Mr. Stout was mistaken. No doubt the wires perpetually received currents from the atmosphere, but they were currents of high tension and very feeble quantity, and did not produce any effect on such instruments as those which Mr. Stout had at his command. He thought that Mr. Stout's views on that point needed confirmation. Mr. Winter alluded to the force of the earth, and said that he believed that force to be much more constant than was generally supposed. He (the Chairman) believed that Mr. Winter was perfectly right, and that idea was one which he had long entertained. It was evident that the sun was exercising a very enormous power over the currents of the earth. They all knew that there was a period of eleven years, during which the sun's spots increased and decreased, and during those perieds aurora were more or less intense, and there was more or less rainfall at the maxima and minima of the spots. Generally, it was quite clear that much of our magnetic force depended upon the sun. About 1850 two observers were looking at the sun with their telescopes in different parts of the country, and they both observed at the same time, and independently, a body apparently flash into the sun, and cause a very visible disturbance of the sun's chromosphere. After that they communicated with each other, and discovered that it had been found at the same moment that all the magnets in the world were disturbed. At first sight it seemed curious that the disturbance of the magnets should be instantaneous with the appearances in the sun, but that wonder vanished in consequence of a recent observation of Prof. Balfour Stewart, who found that the velocity of the transmission of magnetism happened to be the same as the velocity of the transmission of light. Mr. Graves, in his paper, had given some very interesting observations, amongst which he mentioned a connection between earthquakes and earth-currents. That view had been somewhat confirmed by Mr. Varley. It was to be hoped that all the members of the Society would endeavour to bear these points in mind, and make observations upon them. He (the Chairman) believed that Mr. Varley's opinion with regard to the earth-currents proceeding from Ipswich and King's Lynn was somewhat confirmed by the circumstance that we did not get violent earth-currents on our submarine cables generally. It seemed that the sea was so good a conductor that it prevented those great changes of potential which were found on land lines. He had

considered the question whether it was best to retain the ends of a cable insulated during a magnetic storm, or to connect them to the earth. His own opinion was that the cable was safer when the ends were connected. But when they had tensions of 2000 cells, which Mr. Varley believed to exist, it was certainly a serious thing to relieve the cables from the strain of such potentials. Certainly it would not do to attach one end to the earth, and leave the other unattached. He agreed with Mr. Varley in thinking that the earth's magnetism was due to the rotation of the earth through the atmosphere. Mr. Winter had said that in the rotation of the earth there would not be a magnet rotate near a fixed conductor, but he (the Chairman) thought it extremely probable that at great elevations the tenuity of the air was so great that it remained more or less stationary.

METEOROLOGICAL SOCIETY.

"*A Description of a Self-registering Electrical Anemometer and Rain-gauge*," was read by the Rev. F. W. Stow, M.A., F.M.S.

The registering apparatus is on the principle of the Morse telegraph instrument. A Robinson's cap anemometer is arranged to complete an electrical circuit by bringing two platinum surfaces into contact once for every mile of wind that passes. An electro-magnet thereupon draws down a sharp steel point upon a tape of paper, which is drawn by a clock over a grooved roller at the rate of 6 inches an hour. The steel point is weighted and carried at the end of an elastic slip of metal, so that a hole is punched in the paper by the first blow, and the point immediately extricates itself.

The paper, therefore, cannot be torn, even if the contact be prolonged, as may happen in a calm. It is obvious that the number of holes punched in each length of binders represent the velocity of the wind in each hour.

The rainfall is registered by a parallel row of dots upon the same paper. The rain from a 12-inch gauge drops into a small vessel at one end of a balance. From the bottom of the vessel a tube bent into a syphon proceeds. When a weight of 285 grs., equivalent to a fall of $\frac{1}{10}$th of an inch, has entered the vessel, the counterpoise is raised from its support, and the vessel falls till a platinum point at the bottom of it strikes against a platinum-faced spring, thus completing the circuit, and causing a hole to be punched in the tape of the registering machine, which may, of course, be at any distance from the gauge. Meanwhile the water has flowed up to the top of the syphon, which immediately discharges the contents of the vessel, which then rises again to its former position.

The batteries used are a modification of Sir W. Thomson's "specific gravity" Daniell's cells, a disc of zinc 8 inches in diameter being placed in a common round yellow dish 1½ inches above a plate of copper (or lead) of the same size. The whole is filled with a strong solution of sulphate of zinc, and crystals of copper sulphate are dropped to the bottom. The zinc is wrapped in parchment paper, and has holes punched in it to permit the escape of gas. A Leclanché battery was at first tried, but always failed at the end of a few hours. Six cells of the above battery give a powerful and constant current. It was thought that the Leclanché might answer for the rain-gauge where the contacts are much less frequent, but its failure in one or two heavy and continuous rains caused its abandonment.

NATIONAL ACADEMY OF SCIENCE, CAMBRIDGE, MASS., U.S.

Professor Mayer states that he has discovered, by means of the Saxton comparator, that rods of iron suffered a permanent elongation by magnetisation of one hundred and fifty-millionths of an inch. English refined iron gave the maximum of elongation; scrap iron the minimum. Whether the current was gradually increased in intensity, or whether it was sent full charge at once, it produced the same degree of elongation. With one cell the elongation took place in six-tenths of a second; with 25 cells it took place in two tenths of a second. Prof. Pierce thought if the elongation of iron under magnetisation were true, it might make its effect on the earth in an appreciable difference in the length of the day. This could be detected by astronomy. A change in the day of seven-hundredths of a second would be perfectly easy to discover now.

Correspondence.

"GOVERNMENT TELEGRAPHY."

To the Editor of the Telegraphic Journal.

Sir,—Referring to the leading article on "Government Telegraphy," in your Journal of the 15th instant, I beg that you will be so kind as to furnish me with the particulars of any case of delay which has come, or which may hereafter come, under your knowledge.

I endeavour, by a prompt investigation of complaints, to remove the causes of delay, but a general statement of delay does not enable me to put my finger on any special defect.

I am sure that you are desirous of assisting both the Government and the Public, and I therefore trust you will furnish me with such particulars of actual cases of delay as will enable me to apply a remedy where remedy is needed.—I am, &c.,

F. I. Scudamore.

General Post Office,
Reg. No. 30,204.

[The particulars of the case of delay referred to generally in the article, as well as of other instances coming under our knowledge, will be forwarded to Mr. Scudamore. We are "desirous of assisting both the Government and the Public," as Mr. Scudamore states, and we think the aid most surely rendered by following Mr. Scudamore's own admirable policy of publicity and investigation. But we may be permitted to add the opinion that if every member were as energetic in the performance of his duty as is the Chief of the Administration of the State Telegraphs, delays could occur only through accident.—Ed. T. J. and E. R.]

Telegraph-Posts.—In our last and present numbers the difficulty of inserting telegraph-posts in loose earth was treated of by Major Webber and others. Reference was not made, however, to the appliances by which the excavation intended to receive the post is effected. Digging with a spade necessarily loosens the earth around the pole, and considerable time is lost in ramming, &c. Undoubtedly the best means of effecting the excavation is by boring. Messrs. Bohlken's earth-borers are extensively used for this purpose by the German, Austrian, and Russian Governments, and the numerous posts set up by the Royal Prussian Telegraph Company are all inserted on this principle. Recently one hundred and two holes were bored in a day, in exceedingly hard ground, by one man, using this description of instrument.

Delays.—A recent Associated Press despatch states that there are numerous complaints from the public in consequence of the interruption of telegraphic communication between Havana and Kingston. Telegraph despatches are nine days coming, owing to the bad condition of the short land line between Havana and Batabano.

TELEGRAPH SHARE LIST.

Amount per Share.	Name of Company.	Amount paid up.	Feb. 21st.	Feb. 28th.	Mar. 7th.	Mar. 11th.
£		£				
Stock	Anglo-American (Limited)	100	150 152	155 160	165 170	172 173*
10	British Australian (Limited)	All	9¼ 10½	10 10½	10½ 10¾	10½ 10¾
10	British Indian Extension (Limited)	All	13½ 14	14 14½	14½ 14¾	14½ 14¾
10	China Submarine (Limited)	All	10¼ 10½	10½ 10¾	10¾ 11	10¾ 11
10	Cuba (Limited)	All	10 10½	10 10¾	10½ 11¼	10¾ 11¼
10	Eastern (Limited)	All	10½ 10¾	10 10½	10 10¾	10 10½
10	Great Northern	All	11¼ 11½	11½ 11¾	11¼ 11½	11¼ 11½
20	Great Western (Limited)	13	9¼ 10¼	9½ 10	9½ 10¼	9½ 10¾
10	Hooper's Telegraph Works	All	13 13½	11½ 12	11½ 12	12½ 13
50	India-Rubber, Gut. Per., and Teleg. Works	45	36 38	36 37	36 37	36 37
25	Indo-European (Limited)	All	15 17	15 17	15 17	14 16
10	Mediterranean Extension (Limited)	All	6½ 7	6½ 7	6¾ 6¾	6½ 6¾
10	Ditto 8 per cent Preference	All	10 11	11¼ 12¼	11¼ 12¼	11¼ 12¼
20	New York, Newfoundland, and London	10	17½ 18	18½ 19½	25 25½	18½ 18¾
10	Panama and South Pacific (Limited)	2½	— —	— —	— —	— —
8	Reuter's (Limited)	All	10 11	10 11	10¼ 11¼	10¼ 11¼
20	Soc. Transatlant. Fran. (Limited)	All	27½ 28	28½ 28¾	30½ 31	31½ 32
20	Ditto New	15	26½ 27	— —	— —	— —
Stock	Submarine	100	215 220	228 230	225 230	225 230
1	Ditto Scrip	All	2½ 2¾	2¼ 2¾	2¼ 2¾	2¼ 2¾
Cert.	Submarine Cables Trust	100	118 120	119 121	122 127	125 127
12	Telegrph. Construction and Maintenance	All	30 31	29¾ 30¼	31 31½	31 31¼
10	West India and Panama (Limited)	All	7¼ 7¾	7½ 8	8¼ 9	6¾ 9
1000 dls.	West Un. U.S. 7 per cent 1st M.B.	All	89 91	90 92	91 93	92 94

* The Anglo-American Stock advanced on the 11th to 175; then fell to 167 on the announcement of the breaking of the 1865 cable and finally closed at 173.

Students' Column.

Condensation of Electricity.

Condensation of electricity consists in increasing the capacity of a conductor by the inductive action of another conductor approximated to the first and connected to the earth; or in placing two thin sheets of metal parallel to each other, and interposing between them a larger plate of a non-conducting material. The conductors or plates of metal are insulated. The principle is best illustrated by the condenser of Œpinus, a description of which is to be found in any handbook upon electricity. It consists of two brass plates with a sheet of glass between them, one of the brass plates being charged with electricity, and the other connected to earth. If we suppose the collecting plate in connection with the electrical source to be charged with positive electricity, this positive electricity will be held upon or drawn to the surface of the collecting plate opposed to the surface of the condensing plate by the action of the negative electricity induced upon the latter. And in this manner the collecting plate can receive a further charge, the positive electricity it contains being condensed by the attractive force of the negative electricity of the condensing plate. The condensation of electricity therefore includes an increase of electrical density upon a given surface, attained without increase of potential.

Prof. Deschanel says:—To give a rough idea of the increase of capacity obtained by the employment of a condensing plate, let us compare the capacity of a circular disc of 10 inches diameter, accompanied by a condensing plate at a reduced distance of $\frac{1}{10}$th of an inch, with the capacity of a globe of the same diameter as the disc. The capacity of a globe is equal to its radius, and may therefore be denoted by 5. The capacity of the disc is—

$$\frac{25\pi}{4\pi \times \frac{1}{10}} = 125,$$

or 25 times the capacity of the globe. It is, in fact, the same as the capacity of a globe 250 inches (or 20 feet 10 inches) in diameter.

From the preceding example it will readily occur to what practical use the condenser may be put. For the purposes of telegraphy the condenser is employed in comparing the electro-static capacities of cables, the electromotive forces of batteries, in joint-testing, and to prevent earth-currents in submerged cables. The varieties of condenser best known are those of Clark, Varley, and Willoughby Smith. Varley's condenser consists of alternate sheets of tin-foil and very thin tissue-paper saturated with molten paraffin. Clark's condenser is constructed of tin-foil and sheets of thin mica painted over with molten paraffin or shellac. Willoughby Smith's condenser differs only in the insulating material being of prepared gutta-percha containing shellac. Alternate sheets of the tin-foil are connected together, forming two series of plates, one of which serves as the collecting plate, the other as the condensing plate in the condenser of Œpinus.

The force (or condensing force) of a condenser is the relation of the charge that the apparatus is capable of receiving when arranged as a condenser to the charge that the collecting plate alone could receive. To calculate the condensing force, express the total quantity of positive electricity which the collecting plate can take, while under the influence of the condensing plate, by 1, then m is the whole quantity of negative electricity on the second plate. But the quantity of free electricity on the collecting plate is $1-m^2$. Hence $\frac{1}{1-m^2}$ is the fraction which expresses the condensing force. The value of m is determined experimentally by means of the proof plane and the torsion balance. Thus, if m were 0·99, the quantity of electricity which could be accumulated on the collecting plate, under the influence of the condensing plate, would be 50 times as much as the quantity it could receive if alone; while if m were 0·75 the quantity would be 2·28 times as great.

The method of calculating the capacity of a condenser has been so clearly laid down by Prof. Everett that we cannot do better than quote it here. He terms A the collecting plate, B the condensing plate, and C the intervening non-conducting plate (or dielectric), and continues—"The lines of force between the two plates A and B are everywhere sensibly straight and perpendicular to the plates, with the exception of a very small space round the edge, which may be neglected. The tubes of force are therefore cylinders, and the intensity of force is constant at all parts of their length. Since the potential of the plate B is zero, if we take V to denote the potential of the plate A, which is the same as the potential of the conductor, and t to denote the thickness of the intervening plate C, the rate at which potential varies along a line of

force is $\frac{V}{t}$, which is therefore the expression for the force at any point between the plates A, B. The whole space between the plates may be regarded as one cylindrical tube of force of cross-section S, equal to the area of either plate, the two ends of the tube being the inner faces of the plates. The quantities of electricity, $\pm Q$, residing on these faces are therefore equal, but of opposite sign; and as the force changes from nothing to $\frac{V}{t}$, in passing from one side to the other of the electricity which resides on either of these surfaces, we have $\frac{V}{t} . S = 4\pi Q$. Hence the capacity of the plate A, being, by definition, equal to $\frac{Q}{V}$, is equal to $\frac{S}{4\pi t}$. We should," continues Prof. Everett, "explain that, if the intervening plate is a solid or liquid, we are to understand by t not the simple thickness, but the thickness reduced to an equivalent of air. This reduced thickness is, in the case of glass, about half the actual thickness. If s denote an element of area A, and q the charge residing upon it, it is evident, from considering the tube of force which has s for one of its ends, that $\frac{V}{t} . s = 4\pi q$; and the electric density $\frac{q}{s}$ on the element is equal to $\frac{V}{4\pi t}$, which is constant over the whole surface of the plate."

The point offering the greatest difficulty to the mathematical consideration of the question is the influence of the dielectric or intervening plate. For different substances Faraday discovered that there were different powers of induction. Taking air as the unit, he determined experimentally that the mutual induction through 2·24 inches of sulphur was the same as through 1 inch of air. Testing other materials he found that they possessed specific inductive capacities, of which a few follow:—Air or any gas being 1; spermaceti is 1·45; glass, 1·76; resin, 1·77; pitch, 1·80; wax, 1·86; shellac, 2·00; sulphur, 2·24.

In our next number we shall shortly describe some applications of the condenser.

PAPERS FOR JUNIOR STUDENTS.

We promised in our last number to define more concisely the terms tension and electromotive force, and to explain those of intensity, quantity, and resistance. And here we would impress upon the student an idea of the value of a concise definition when committed to memory. By committing the definition to memory the mind can, as it were, dwell upon the intended meaning, which, though dim at first, gradually becomes clearer, until the whole subject stands in a bright light. Let us begin with a definite understanding of the meaning of the term *tension* or *potential*. *Potential* or *tension*, then, depends upon the forces (attractive or repulsive) mutually exerted upon each other by particles at a distance; and this distance, for the purposes of reasoning, may be considered as extremely great or extremely small.

Electromotive force is the result of a difference of tension or potential between any two points. Thus if in a tube of water the pressures are equal throughout, the water remains quiescent; but if we exert pressure upon any one point in the water, a current of water is formed from that point to a point of less pressure. The difference between the pressures or differential force tending to produce motion in the water is analogous to the difference of potential between the plates of a galvanic battery tending to produce an electrical current. If we take as the unit of potential the tendency of copper to combine with the oxygen of the acidulated water of a galvanic couple, we shall find that, taking as positive plate, say, an amalgam of sodium or an amalgam of zinc, we have with the sodium a powerful current (the affinity of sodium for oxygen being very high); with the zinc, not so powerful a current; and that if we substitute for the sodium or zinc another copper plate, the difference of potential sinks to zero, and no current exists.

Resistance is the obstacle opposed by the conductor to the passage of the current. In the case of a pipe of water the sides of the pipe oppose, by cohesion or friction, a certain force to the passage of the water. The resistance overcome by the water must be of such nature that twice the quantity of water will flow through any one pipe when twice the head is applied. This would not be the result of a constant mechanical resistance, but of a resistance which increased in direct proportion to the speed of the current; thus the electrical resistance must not be looked on as analogous to a simple mechanical resistance, but rather to a coefficient by which the speed of the current must be multiplied in order to obtain the whole mechanical resistance. Thus, if the electrical resistance of a conductor be called R, the work, W, is not equal to CRt (current, resistance, time), but to $C \times CR \times t$, or $W = C^2Rt$, where C may be looked upon analogous to a quantity moving at a certain speed, and CR as analogous to the mechanical resistance it meets with in its progress, and which increases in direct proportion to the quantity conveyed in the unit of time.

Quantity.—The quantity of electricity flowing through a conductor depends upon the electromotive force and the size of the plates of the battery, as well as upon the resistance offered by the conductor.

The *intensity* of an electrical current is generally understood to be its power of overcoming resistance. Thus, while the term tension or potential has a hypothetical foundation, that of intensity has a practical signification.

The difference between quantity and intensity may be compared to the difference between two lights, quantity being represented by the light obtained from the ignition of a large surface of spirit of wine, and intensity by the candle-flame, or better by the electric spark and oxyhydrogen jet.

But before we can enter further into scientific detail we must first ascertain the means by which the nature of the current is registered or made visible. By following this course we shall more readily and speedily arrive at some practical profit, because we shall sooner acquire an acquaintance with the principle of the construction of all electrical instruments. To ascertain these means, it is necessary first to learn the effects of the electric current upon the conductor through which it flows. These effects are two:—

1. Heating.
2. Magnetic.

The heating effect does not enter very largely into the practical application of electricity. It is, however, the source of the electric light, and the following is the *rationale* of the action. Carbon is a very bad conductor of electricity,—that is, it offers a very high resistance to the electric fluid, which resistance increases in the manner we have previously described. Now when a current of great quantity and sufficient intensity is caused to pass between two carbon points, the latter become heated in the struggle that the electric fluid makes to force its way, and so intensely heated that the carbon is raised to whiteness, and finally fused. A curious reaction aids this action. It is found that a conductor when heated offers a higher resistance than at the normal temperature, and, as a consequence, the more heated the graphite-carbon becomes the higher rises its resistance. A similar effect may be obtained with a lower battery power and a very fine platinum-wire: the battery, however, must be one affording a

considerable quantity of electricity. These results are of very slight application, and we pass them over, until, in a later paper, when we shall have acquired a knowledge of Ohm's law, and return to the mathematical consideration of the subject and the relation of this to work done.

In our next number we shall deal with the magnetic effects of the electric current and its application.

Notes and Queries.

For Electroplaters.

Why cannot a pattern or ornament (similar in character to the old style called damascening) be either printed or pencilled upon the articles to be plated with a varnish or medium which would prevent the deposit of the electro-silver or gold upon the parts which it covers, and which would be easily removed after the article has been electro-gilt? If this could be done, a wide field would be opened up for its application; as, for instance, supposing an article was first plated with silver, and then a damascene pattern was put on the silver in the manner above described, and then the parts left uncovered were plated with gold, we should have a work of art of a very high class, and at a comparatively low cost, the pattern being gold upon silver or *vice versa*.

Moulds.—In order to render moulds of plaster or gutta-percha used in electrotyping conducting, the use of a solution of 1 grm. of silver nitrate, 2 grms. of water, 2·5 grms. of ammonia (sp. gr. 0·96), and 3 grms. absolute alcohol, is recommended. Before the coat is quite dry it is exposed to a current of sulphuretted hydrogen.

Deposit.—(1). Black deposit is produced when the current is so strong, as compared with the strength of the salution, that hydrogen is set free at the negative plate. (2). Crystalline metal is deposited when the current is so weak, as compared with the solution, that there is no tendency to evolve hydrogen. (3). Metals are reduced in the reguline state when the current so balances the strength of the solution that it is insufficient to actually set gas free, but produces a strong tendency thereto. There are also two forms of crystalline deposit—one of a sandy, loose character, due to deficiency of the quantity of current in a strong solution; the second from a large quantity of current as compared with the size of the plate, thus by using a large anode with a small cathode in a strong solution, large crystals of extreme hardness are produced.—*Smee.*

Battery Power.—The electromotive forces required for depositing metals are in Volts about:—

1.	Copper	0·5 to 1·0
2.	Silver..	1·5 „ 2·0
3.	Gilding	0·3 „ 0·5

That is to say, 1 Smee or Daniell is enough for coppering, 3 Smees or 1 Grove for silvering, and 1 Smee or copper cell for gilding.—*Sprague.*

Plumbago.—The plumbago of commerce comes mainly from the Island of Ceylon, in India, but it is found in many parts of America. It is therefore generally known as Ceylon plumbago. The formation most common, in the pure state, is that of laminated crystals, elongated at right angles with the sides of the vein, if not more than from 4 to 6 inches wide. To the electrotyper, absolute purity in his plumbago is a necessity, and hence any adulteration will discover itself at once on trial. From the "prime lump" should be selected the very choicest lumps, and these should be pulverised till the particles will not glisten, but the mass becomes a dead black. It cannot be made fine enough if separated by bolting, but must be separated by floating either in water or air. The simplest method is the water separation, and during the process it should be treated to a bath of dilute sulphuric acid, which will take up the particles of spar and iron, leaving the sulphates of lime, magnesia, and iron easily washed out.

Nickel-Plating.

"Electro" writes to know if some subscriber will inform him how to make a good nickel solution for plating purposes, the method of working, and the battery power required.

Galvanometer Resistance.

Mr. John Smythe wishes to know how Mr. Mance connected up his galvanometer to obtain its resistance, using the same galvanometer to obtain the deflection?

Australian Telegraphy.—A return as to the length of telegraphs existing in New Zealand shows that in 1871 that colony had 3286 miles of line. In 1870 the corresponding length was 3162 miles; in 1869, 2777 miles; in 1868, 2637 miles; in 1867, 1447 miles; and in 1866, 1398 miles.

Societies' Meetings for the Month.

The Society of Telegraph Engineers.—March 26.—April 9. At 7.30 p.m.

Geological Society.—March 26.—April 9. At 8 p.m.

Meteorological Society.—March 19, at 7 p.m.

To Correspondents.

A Constant Reader.—No detailed account has been published. Mr. Werdermann, C.E., would perhaps supply the information.

Inventor.—The observation has been made before, and drawings have been given in numerous works on Natural Science.

Walsingham.—Coal must be very high indeed in price before electricity can supersede steam as a motive power. The slightest acquaintance with engineering would show you this.

W. Y. Naylor.—The Submarine Report. Apply to any scientific bookseller.

J. Smythe.—Your notes on earth-currents shall be inserted in our next. We insert your query.

G. B. Compton.—Your query arrived too late to be answered fully in this number. The British Telegraph Manufactory will perhaps forward prospectus. No batteries are employed. The bells are worked by the instrument described in our article.

Books Received.

"Practical Suggestions to Inventors." By Julius Hall.

"Electricity and Magnetism as Curative Agents." By P. W. Seymour.

In One Volume, 8vo., with over 120 Woodcuts and 4 Plates of Machinery and Apparatus, price 14s., cloth.

A Handbook of Practical Telegraphy. By R. S. CULLEY, Member Inst. C.E., Engineer-in-Chief of Telegraphs to the Post Office. The Fifth Edition, revised and enlarged.

"Mr. Culley's book is of great value to all who have anything to do with telegraphy, or who desire to become familiar with the subject in a practical way."—*Scientific Review.*

"At the present time, when the entire telegraph system of the country is being revolutionised, and when large numbers of persons are being primarily instructed in the principles of telegraphy, a re-issue of Mr. Culley's excellent work is very opportune, if not an absolute necessity."—*Scotsman.*

"The book, which is abundantly illustrated, forms the best vade-mecum for the engineer or operator of the electric telegraph, whether by sea or land, with which we are acquainted."—*English Mechanic.*

London: LONGMANS, GREEN, and CO., Paternoster Row.

Royal School of Mines.—Professor GUTHRIE, F.R.S., commenced a Course of Sixty-two Lectures on PHYSICS (including Sound, Heat, Light, Electricity, and Magnetism), with work in the Physical Laboratory, at the New Buildings, Exhibition Road, South Kensington, on Monday, the 10th of March, at Four o'clock, to be continued on every week-day but Saturday. Fee for the Lectures £4, for the Physical Laboratory £5 per course; or £13 for all the courses.

TRENHAM REEKS, Registrar.